# AUSTRALIAN FUELS, ENERGY, AND GREENHOUSE GAS EMISSIONS: IMPLICATIONS FOR THE 21$^{ST}$ CENTURY

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## INTRODUCTION

Australia with a population of only 18 million has abundant reserves of black and brown coal/lignite (hereafter referred to as brown coal), and substantial reserves of oil, natural gas, and uranium. Being a very large temperate-to-sub-tropical continent covering 7,682,300 km$^2$ (Australian Bureau of Statistics [ABS, 1997]), approximately equivalent in area to that of the continental U.S., Australia experiences abundant sunshine and significant windy regions. These natural characteristics along with the fossil fuels already mentioned, signifies the country as energy resource rich. As a consequence of its fossil fuel resources and its large reserves and diverse range of minerals, Australia has become both an export supplier of raw commodities, such as coal and iron ore, and of secondary processed materials, such as aluminium ingots and uranium yellowcake. These mining and mineral processing developments, along with the increased infrastructure and industrial, commercial, and domestic demands, and the large travel and transport distances, particularly over the last 25 years, have resulted in the country's greenhouse gas emissions being among the highest in the world on a per capita basis, (1.4 % of global greenhouse gas emissions [Skelton, 1997]).

This paper addresses fossil fuel resources and other energy sources in Australia, electricity generation and energy consumption, greenhouse gas emissions, and recent economic and structural changes in the electricity and gas industries. Issues to be briefly considered include new energy technologies, fuel alternatives, $CO_2$ reduction strategies, and future energy developments.

## FOSSIL FUELS AND ENERGY SOURCES

By far the largest of Australia's fuel resources is coal, including bituminous, sub-bituminous, and brown coal, the resources of which are shown in Table 1. Australia is the world's largest exporter of black coal, exporting almost 146 million tonnes in 1997 (Australian Bureau of Agricultural and Resource Economics [ABARE, 1997]). It ranked as the fifth largest producer of hard coal in 1996 (World Coal Institute web page). In 1997 production was 6.7 % higher than that in 1996 at 207.5 million tonnes. The large black coal resources, mostly bituminous, are found in Queensland and New South Wales (NSW). Much smaller quantities of sub-bituminous coal exist in Western Australia, Queensland, and NSW. Brown coal is substantially located and mined in Victoria and lesser quantities in South Australia. This resource represents about 27 % of the Australia's total energy reserves.

Table 1 also shows the currently reported resources of gas, oil, and uranium. Australia is the second largest producer in the world of uranium (Uranium Institute, 1997) but it uses no uranium domestically for generating electricity. Self-sufficient in oil to the extent of 73 % at present, Australia is predicted to see a decline in self-sufficiency to about 61 % in the next five years, assuming no discovery of a major oil field [Private Communication, 1998]. Natural gas is produced in significant quantities on-shore, mainly in South Australia, Northern Territory, and Western Australia, as well as off-shore Victoria and Western Australia where the gas fields are much larger than on-shore. Significant quantities of liquefied natural gas are shipped in cryogenic form overseas but within Australia gas is the predominant fuel for domestic and industrial applications.

Australia's latitude enables it to receive monthly mean daily solar irradiation ranging from a minimum of 5.0 MJ/m$^2$ in Hobart and Launceston, Tasmania to a maximum of 31.0 MJ/m$^2$ at Geraldton, Western Australia, (Lee, Oppenheim and Williamson, 1995). Its solar potential is under utilised for energy generation but significant use is made of it for drying and heating purposes by the agricultural and chemical industries, e.g. for bagasse, salt, and by the domestic sector, e.g. for clothes drying, hot water systems. Australia is largely a dry continent, exhibiting substantial hot regions and variable but not extensive rainfall, from a minimum median annual rainfall of 100 mm at Lake Eyre in South Australia, to a maximum median annual rainfall of 4,048 mm at Tully in Queensland (ABS, 1997). These conditions along with extensive land clearing have led, in general, to sparse tree cover in areas beyond a relatively narrow strip around the eastern and southeastern seaboard and the island state of Tasmania.

Significant wind energy sources are located around the Australian mainland coast and southern islands, e.g. Tasmania, King Island, Lord Howe Island. Typically at selected points the wind speed will exceed 6 m/s at a height of 10 m, sufficient for a sustainable wind energy farm [Osborne, 1993].

Apart from solar and wind energy, other renewables available as energy sources in Australia are biomass and hydro. Particularly for Queensland, NSW, and Tasmania, there are significant quantities of bagasse from sugar cane production and other agricultural residues (e.g. cotton trash), forestry residues, saw mill waste, and municipal wastes (Spero, 1998). However, they are small in relation to the coal reserves and suffer from large volume to mass ratio, big distances between recovery points and end usage location, and consequently often greater cost and seasonal variability.

## ELECTRICITY GENERATION AND ENERGY CONSUMPTION

Current electricity demand in Australia is around 160,000 GWh per year. Growth rate in electricity demand over the last decade has been 5 to 7 % per year [Schaap, 1998]. A lower growth rate is likely over the next decade, although the power demand in the manufacturing and commercial sectors is projected to be higher than that in the residential sector.

On a national basis the electricity generation supply mix is shown in Table 2. However, on a state by state basis there are significant variations, e.g. in Queensland and NSW 98 % and 93 % respectively of electricity generation is coal based; in Tasmania, virtually 100 % is based on hydro (Electricity Supply Association of Australia Limited, [ESAA, 1997]).

Brown coal, containing between 60 % and 70 % water, is Victoria's major fuel source for generating electricity, representing 97 % of the supply mix and producing 39,755 GWh in 1995/96 (ESAA, 1997). Victorian brown coal is also used to make briquettes in a cogeneration plant having a capacity of 1.2 million tonnes although recently operating at about half that throughput. The briquettes are used for steam raising, heating, and electricity generation by industry, hospitals, and residential homes (heating/cooking). A significant proportion of the production is exported to niche markets including Germany. The advantages of this solid fuel are low $NO_x$ and $SO_2$ emissions on combustion, relatively low moisture (13-14 wt %) compared to the parent coal, very low mineral matter content (<2 wt %), ease of ignition and good combustion in a conveniently transportable solid form. Although the coal is reactive in the dried form, the briquettes can be safely stored and shipped in bulk to markets as far away as Europe.

Considering total energy consumption, it is noted that in 1995-96 the three dominant and virtually equal sectors are electricity generation, transport, and manufacturing at 26.9 %, 26.2 %, and 25.5 % share respectively. Far lower proportions of energy were consumed in the residential, mining and commercial sectors at 8.1 %, 5.1 % and 4.2 % respectively; the agriculture and other sectors were 1.5 % each. Over the next decade, the three major sectors are predicted to have similar shares of energy consumption but the mining sector will grow (to 6.5 %) and the residential decline (to 6.9 %) [Private Communication, 1998].

## GREENHOUSE GAS EMISSIONS

Strategies for controlling and reducing greenhouse gas emissions are now receiving increased attention, especially in view of the recent Kyoto Greenhouse Summit in November 1997. In 1994, stationary energy (i.e., largely for power generation) produced 37 % of the total of $CO_2$-equivalent greenhouse gas emissions in Australia whereas the transport sector generated slightly less than a third of this amount (ESAA Greenhouse Challenge Workbook, August 1997). Given the commitments from Kyoto, and the Australian Federal Government Greenhouse Challenge Program, activities are in progress that are likely to change the type, mix, and use of fuels, as well as the implementation of new technology, as Australia enters the next century. The Australian Federal Government has also made a commitment to redefining strategies for land use clearing and forestry as well as defining objectives and offering incentives to enhance the use of renewables towards achieving a net reduction in Australia's release of $CO_2$, methane and other greenhouse gases. To stimulate the use of renewables, the Australian Government, for example, has set as a requirement an additional 2 % of electricity to be derived from renewable energy by 2010.

Already, efforts to increase efficiency of current plant equipment, and the installation of more efficient technology have begun as a means of reducing greenhouse gas emissions. For example, in Victoria, HRL Limited has anticipated the need for higher efficiency in future brown coal use (and low rank coal, in general) for electricity generation and has just completed a 3.5 year-development project, investigating the innovative technology of Integrated Drying Gasification

Combined Cycle (IDGCC) [Johnson et al, 1997]. The IDGCC concept essentially replaces a separate atmospheric pressure dryer before the gasifier and a high pressure gas cooler after the gasifier with a direct contact entrained flow dryer, which is a high-pressure pipe. Increased generation is achieved in the gas turbine cycle by the additional mass flow of the evaporated moisture passing through the turbine. The process is schematically shown in Figure 1. The project successfully demonstrated at a 10 MW scale a 20-30 % improvement in efficiency and a corresponding reduction in $CO_2$ emissions and cost over conventional thermal power generation using the same coal.

Other efforts to reduce greenhouse gas emissions have included the development and demonstration of photovoltaic receptor arrays and wind farms, albeit on a small scale at this stage. One Australian company, Pacific Solar, aims to construct its first facility for making 20 MW per year of photovoltaic modules in 1999 and be in operation by the last quarter of 2000. This first facility will produce, through a radically different manufacturing process, sufficient relatively low cost solar modules to meet the demands of 7000 homes per year, representing under 5 % on average of Australian homes built each year. The target installed cost is to be competitive with the current delivered price of conventional electricity in Australia (AUD 10-15 cents per kWh) [Lawley, 1998].

Wind farms are also on the agenda for achieving greenhouse gas reduction in Australia. States including Western Australia, N.S.W., Victoria and Tasmania have active programs, privately and publicly sponsored, to produce electricity from wind turbines. In Victoria, for example, a private company, Energy Equity Limited, has recently been granted approval to build Australia's largest renewable energy project excluding hydropower. Subject to resolving local objection, the company will install 35, 60-metre high wind turbines, about 400 metres apart, based on three sites near Portland, southwestern Victoria and generating 20 MW of power for domestic distribution (Watkins, 1998).

Electricity generation companies using coal as a fuel are taking steps to reduce $CO_2$ emissions apart from just increasing energy efficiency of existing plant. Plantations of fast growing trees have been established in the different regions adjacent to power stations and elsewhere. In Victoria, by the end of 1992, 1409 hectares of pine and eucalypt trees had been planted in proximity to the brown coal-fired electricity generation sites [State Electricity Commission of Victoria, 1992]. In addition, the various electricity generation companies and their consultants are watching developments in the sequestration of $CO_2$ such as via liquefaction and storage in deep caverns, and photosynthesis by specific algae. However, sequestration of $CO_2$ could cost AUD $3-4 cents per kilowatt-hour, virtually doubling generation costs.

Adopting a "business as usual approach", the baseline Australian scenario for $CO_2$ emissions was projected to grow by 45 % between 1990 and 2010. In the Kyoto Protocol, Australia has been granted a national emissions budget of 108 % of the 1990 level. Given an estimated 20 % in population growth over next 20 years and an economic growth of 1.5 % per year, it has been concluded that absolute reductions would not have been possible and the special allowance was needed. Assuming $CO_2$ credits for reduction in land clearing and other changes in the forestry sector, it is possible that the energy sector emissions budget could approach 125 % of 1990 and still meet the Kyoto target for national greenhouse gas emissions for the period 2008-2012. Future developments in $CO_2$ emissions trading are also likely to offer the potential for offsetting expansion in the Australian energy sector (Key Economics, 1998).

## ECONOMIC AND STRUCTURAL CHANGES IN ELECTRICITY AND GAS INDUSTRIES

The State of Victoria has led the way in the privatisation of the electricity industry in Australia. The four generating companies, privately owned by various consortia of international and national companies, are now operating in a deregulated market. Approximately AUD $9,600 million has been paid for the 6000 MW of brown coal generating plants making premature closure an unrealistic option. The distribution companies are also under private control but not fully deregulated until 2001. Privatisation and deregulation of the gas industry is also progressing with sections of the former government-operated gas distribution entity being corporatised. Other Australian states are in various stages of privatisation of the electricity industry, with South Australia proceeding next.

The very substantial investments made in the Victorian electricity generating utilities are having major consequences. These include increased availability of generation plant (by 10-15 %), planned extension to operating life of the plant from 30 to 50 years typically, and new competitive constraints on the price of electricity "at the fence". The current effect of the latter is to drive the price dramatically downwards. In addition, a comprehensive review of personnel levels, maintenance contracts, the implementation of new technology, environmental control and monitoring equipment, to name some issues, has led to radical changes concomitant with significant expenditure reductions. Economics is a major driver and long-term strategic planning needs are evaluated on a strict cost-benefit analysis. The new forces of economic and structural change will thus have a substantive and diverse impact on the development and practice of the electricity and gas industries as well as on the response of the consumers in the 21st Century. For future power requirements, gas is available particularly for peaking power, while advanced low rank coal technologies, having been demonstrated, will achieve substantial efficiency improvements in future brown coal plants.

## CONCLUDING REMARKS

Coal is still Australia's dominant fuel resource for energy generation with reserves lasting about 550 years for brown coal and about 250 years for black coal, at present rates of usage, compared with reserves of oil and gas lasting approximately 40 and 60 years respectively. Coal fired power generation is forecast to be Australia's dominant stationary energy source well beyond the year 2000. Efforts are highly likely to be made to increase the use of alternative fuels, such as gas and biomass, and to implement new technologies along with alternative energy source options, such as photovoltaic arrays and wind power. However, their cost-effectiveness in relation to total plant investment will be closely scrutinised as the number of Australia's generation facilities are privatised. Also, fuel substitution on a large scale is a limited option due to cost, location, and availability factors but the creative use of biomass, say through reforestation, and a $CO_2$ emissions trading mechanism may provide alternative offsets to the greenhouse gas impact of energy expansion. Nonetheless, Australia in the 21st Century will probably see a greater mix of energy/fuel sources to meet the electrical, industrial, agricultural, and transport demands of the growing economy while concurrently endeavouring to limit the release of greenhouse gas emissions.

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**Table 1: Estimated Resources of Australia's Principal Fuels as at 1996**

| Fuel | Quantity | Reference |
|---|---|---|
| Coal: Black | Very large+ | BRS (1997)++ Mineral Resources |
| Brown | > 200 Giga tonnes | BRS (1997) - Mineral Resources |
| Natural Gas | 1857 Tera litres | BRS (1997) - Oil and Gas |
| Oil | 111 Giga litres | BRS (1997) - Oil and Gas |
| Uranium (as U) | 895 kilo tonnes | BRS (1997) - Mineral Resources |

+ Demonstrated recoverable resources are 55 Giga tonnes
++ Bureau of Resource Sciences

***Table 2: Australian Electricity Generation Supply Mix in 1995/96***

| Electricity Generation: 165,062 GWh | |
|---|---|
| • Black coal | 56.8 % |
| • Brown coal | 25.9 % |
| • Hydro | 9.5 % |
| • Gas | 7.3 % |
| • Oil | 0.5 % |

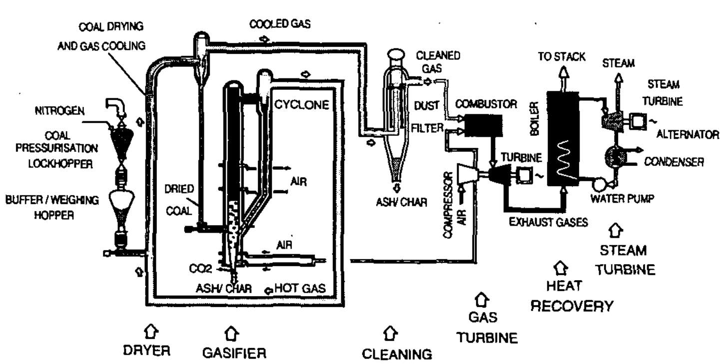


**Figure 1: Schematic of the Integrated Drying Combined Cycle (IDGCC) Process**